Mapping the Acoustic Communication of Killer Whales

A research proposal submitted to Glacier Bay National Park & Preserve by

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ABSTRACT

Much is known about the nature and context of vocal behavior in killer whales but its function is still not understood. Individual killer whales may call primarily to coordinate behaviors within a group, or they could vocalize to contact other groups in an area. Noise from human activities has been identified as a major threat to the well-being of marine mammals and potentially interferes with killer whale communication by restricting the range over which animals can hear each other. Identifying the function and range of communication is therefore important to assess the impact of anthropogenic noise on killer whales. During two field seasons in Southeast Alaska, we plan to measure the loudness of calls of mammal-eating killer whales to determine the distance over which these can be heard. We also plan to monitor the acoustic behavior of groups to find out where and when the animals vocalize. This information will be synthesized into a spatial acoustic model allowing us to determine the area in which other killer whales or prey animals can detect a given call. Determining whether killer whales preferentially vocalize in places where they can be heard over large distances or in acoustically confined areas such as small bays or inlets will tell us whether calls are directed towards other groups or at fellow group members. Modeling the propagation of killer whale calls in environments with different levels and types of man-made noise will illustrate the extent to which such noise limits the communication range of killer whales.

INTRODUCTION

Killer whales in the Northeast Pacific

The waters off the west coast of North America are home to two distinct populations of killer whales that differ in many aspect of their natural history and ecology. *Resident* killer whales feed exclusively on fish, predominantly on salmon, while *transient* killer whales feed only on marine mammals and occasionally on seabirds (Ford *et al*. 1998). The two forms do not interbreed and rarely interact. Killer whales live in stable social groups of maternally related individuals. Maternal groups of resident killer whales have no emigration and both male and female offspring travel with their mothers for life (Bigg *et al*. 1990). The social organization of transient killer whales appears to be somewhat more fluid, and some males and females disperse from the matriline upon reaching sexual maturity.

Acoustic communication in killer whales

Both types of killer whales produce echolocation clicks for orientation and prey detection, as well as two types of communicative sounds: high-pitched whistles, and tonal pulsed calls. While much research has documented the structure of pulsed calls and whistles, as well as the behavioral context in which they occur (e.g., Ford 1989; 1991; Thomsen *et al*. 2001), fundamental questions about the function of acoustic communication in killer whales remain to be answered. Whistles can only be heard over short distances and occur most frequently in social contexts (Thomsen *et al*. 2002). Pulsed calls travel over many kilometers (Miller 2000a) and may function in mid- and long-range communication. Pulsed calls encode information about a caller's identity (Ford 1991), and the distance and direction of a calling animal (Miller 2000b). However, we currently do not know who the intended recipient of the communication is. Killer whales may vocalize to communicate with fellow members of the same social group. Alternatively individuals may emit calls to establish contact with other groups farther away. The group-specific repertoires of killer whales include several stereotyped call types, and these two functions may be served by different call types.

Resident killer whales feed primarily on salmon, a prey with very poor underwater hearing (Hawkins & Johnstone 1978). In contrast, transient killer whales feed on marine mammals that can detect killer whale calls from a large distance and move away when they hear the transients' calls (Deecke *et al*. 2002). Transients therefore pay a much higher cost for vocal behavior since they alert potential prey animals in the area every time they call. Because of this cost, we would expect transient killer whales to vocalize only in situations when the benefits of acoustic communication are at least equally high. This will make it easier to identify what precisely these benefits may be.

Killer whale communication and anthropogenic noise

Killer whales rely extensively on acoustic cues to detect food, orient themselves in their environment and to communicate. The world's oceans are becoming an increasingly noisy environment due to sounds generated by human activities such as vessel traffic and seismic exploration. By decreasing the distance over which killer whales can echolocate and communicate, the increased levels of background noise levels could have severe impacts on the ability of these animals to make a living off the west coast of North America. While captive studies have yielded much information on the hearing abilities of killer whales and their perception of noise (e.g., Bain & Dahlheim 1994; Szymanski *et al*. 1999), these findings have yet to be combined with field observation to see to what extent different types of anthropogenic noise affect the detection and communication distances of killer whales in the wild.

PROJECT

Objectives

The aim of our proposed study is to collect information on the loudness and frequency composition of calls of transient killer whales in Southeast Alaska, as well as to determine the locations where vocal behavior occurs. In addition, we plan to measure the loudness and composition of natural and anthropogenic noise in this area. We will combine these data with information on the hearing ability of killer whales from captive studies to model the propagation of killer whale pulsed calls through the environment and to identify the area over which they can be heard with and without background noise. This spatial acoustic model will allow us to address the following questions:

What is the range of the vocal communication of transient killer whales? We plan to determine the distance over which a given call can be heard by other transient killer whales.

Who are transient killer whales addressing their acoustic communication to? Due to the high cost for vocal behavior, transients should vocalize preferentially in areas where they cannot be heard over large distances if acoustic communication is directed at fellow group members. However, if acoustic communication serves to establish contact with other groups in the area, transients need to call at locations where the calls cover a large area.

How does noise affect the range of killer whale communication? We will assess how different kinds of natural and anthropogenic noise affect the distance over which transient killer whales can detect each other's calls.

Field Research

The field work will be conducted during two field seasons in Southeast Alaska in the waters of Glacier Bay, Icy Strait, Stephens Passage and Frederick Sound. During the first half of the first season we plan to use the procedure of Miller & Tyack (1998) to measure the loudness of calls of transient killer whales. This method determines the distance to a given sound source from the input of two arrays of hydrophones (underwater microphones), which in turn allows calculation of the loudness of the sound at the source. Funding for this part of the study has been requested from the Alaskan Fisheries Development Foundation.

During the second half of the first field season and the second season we will follow groups of transient killer whales in a small vessel. We will use a towed hydrophone to monitor the vocal behavior and will determine location of the group at regular intervals using a global positioning system. Any vocalizations will be recorded on a computer hard disk for subsequent analysis. To ensure that no calls are missed, we will measure the distance to the animals every time they surface using laser range finders and will only collect data when within 200m of the animals. In order to minimize our impact, we plan to use an extremely quiet 4-stroke outboard engine when following killer whales. We have requested funding for this aspect of the study from the National Geographic Society, but require additional funds to complement data collection in the waters of Glacier Bay National Park and Preserve.

During both field seasons we will record various types of natural and human-generated noise. Natural sounds include wave, rain and ice noise, and anthropogenic sounds are the noise generated by ships of various sizes (small speed boats to cruise ships). For vessel noise we will measure the distance to the recorded ship with laser range finders. The recordings will be used to determine the frequency composition and the loudness of the various types of noise.

Mapping the Communication Space

The loudness of a sound at a given location in the marine environment depends on the sound's original loudness and frequency composition, the distance from the sound source, depth and temperature profile of the water, as well as the bottom substrate and topography. Whether an animal can detect the sound furthermore depends on the animal's hearing ability and the level and frequency composition of background noise. Once we have collected data on the physical properties of pulsed calls of transient killer whales, we can therefore determine the loudness of a given call at various distances using information on the topography and water conditions in the area. Dr. Richard Pawlowicz, a physical oceanographer at the University of British Columbia, Department of Earth and Ocean Sciences, will act as a consultant for this aspect of the study. An example of a simple sound propagation model is given in Figure 1. Determining the loudness of the call at different locations allows us to identify the area in which other killer whales can detect a call using frequency-dependent hearing thresholds obtained in captivity (e.g., Szymanski *et al*. 1999).

We can use this sound propagation model to determine whether transient killer whales preferentially call in places where they can be heard over large distances or in confined bays or inlets where their calls do not travel very far. For each encounter, we will identify the area 'ensonified' by the animals and contrast it statistically to the hypothetically area covered if the animals had vocalized at random locations along their path. An observed detection area that is larger than the random scenario shows that the animals preferentially call in places where they can be heard over large distances and suggests that the animal attempt to communicate with members of different, more distant groups. If on the other hand the observed detection area is smaller, this shows that the animals attempt to remain acoustically cryptic and suggests that acoustic communication is primarily directed at fellow group members.

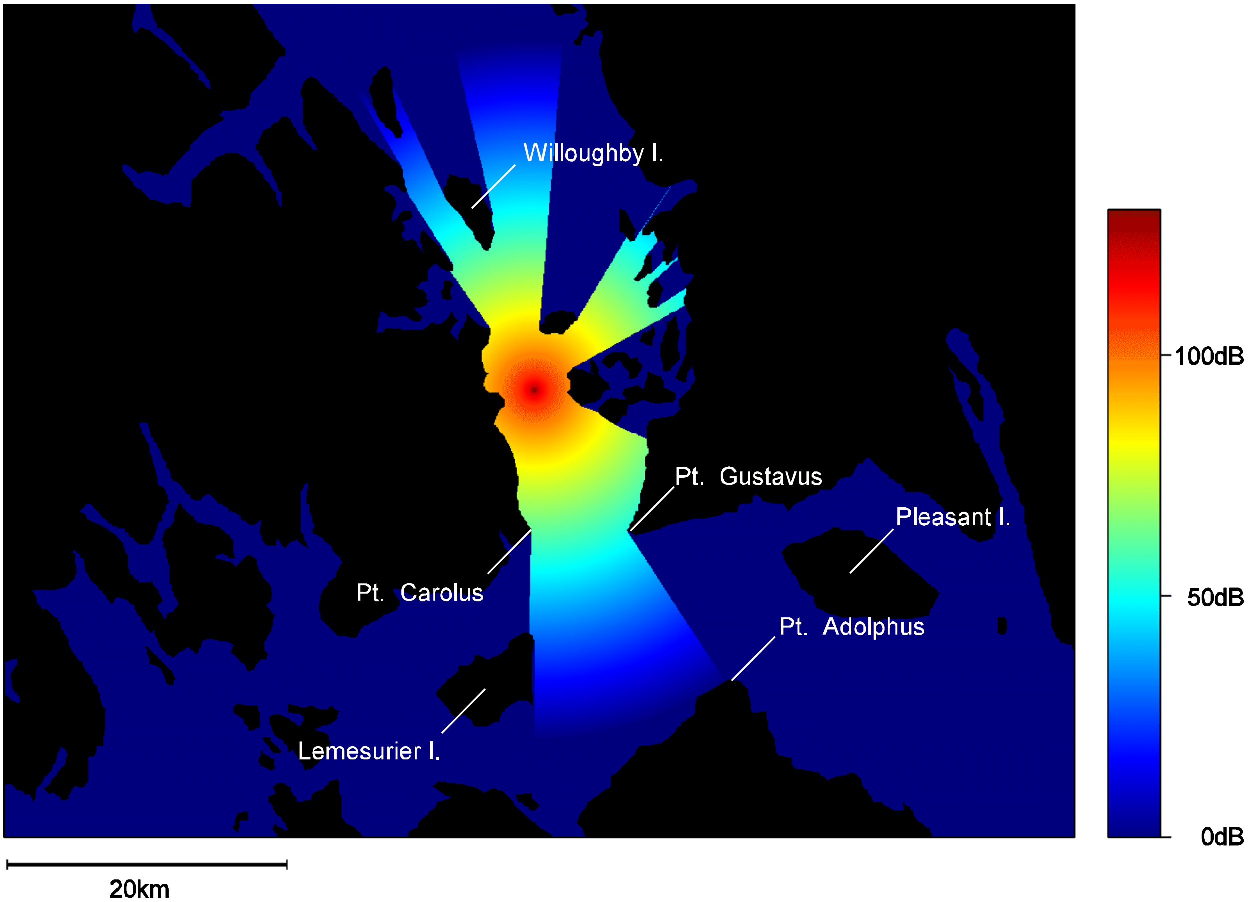

Figure 1: Predicted propagation of a call from a transient killer whale vocalizing in Sitakaday Narrows, Glacier Bay National Park (58º30.8N, 136º03.9W) assuming a source level comparable to that of resident killer whale calls (see Miller 2000a).

Determining the Effect of Anthropogenic Noise

Once we can model the propagation of killer whale calls through a quiet environment and the range over which other killer whales can hear them, we can determine the effect of different types and levels of background noise on killer whale communication. To what extent a certain type of noise limits the range over which killer whales can detect each other's calls depends on the loudness of the noise, as well as whether its frequency composition overlaps with the frequency range important for killer whale long-range communication. Our model will therefore allow a given noise level to be translated into a reduction in the distance over which killer whales are able to communicate.

We will compare the reduction in communication range from noise occurring naturally in the animals' environment such as noise from rain, waves, or icebergs near tidal glaciers with that from noise from various types of boats and ships. This will put the effect of anthropogenic noise into perspective to that of noise which the animals experienced previous to human activity and have presumably evolved to cope with.

EXPECTED RESULTS

This study will address both theoretical and applied questions about the acoustic communication of killer whales. It will provide valuable information on the design of the communicative calls of killer whales specialized to feed on marine mammals. Comparisons with information from fish-eating resident killer whales (e.g., Miller 2000a; Miller 2000b) will help illustrate how differences in the hearing abilities of the prey have shaped the communication signals of different killer whale populations. Determining the range over which killer whales are able to communicate will delineate the role of acoustic communication in the social interactions of killer whales and help determine the appropriate spatial scale at which these interactions need to be examined. Identifying who the intended recipients of acoustic communication are presents a crucial first step towards establishing the function of vocal behavior in these animals. Finally, by determining how anthropogenic noise affects the communicative range of killer whales, this study will provide information on how such noise interferes with acoustic communication, and the distance over which interference occurs.

The primary outcome of this study will be the sound propagation model. This model can easily be applied to other geographic areas, and can be modified to determine the propagation of sounds and communication range of other marine animals. The sound propagation model therefore provides a valuable tool to address future questions of acoustic communication in marine animals and the impact of anthropogenic noise on these communication systems. In addition, we expect three scientific publications to result from this study. The first will compare the loudness, frequency content and communication range of calls of transient killer whales with those of fish-eating residents. The second article will address the question where transient killer whales vocalize preferentially to determine the intended recipients of the acoustic communication. The third publication will determine the effect of human-generated noise on the communication system of transient killer whales. We plan to submit these articles to *Marine Mammal Science*, *Animal Behaviour* and *Behavioral Ecology and Sociobiology*.

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